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# Investigation of intervalence band absorption in type-II QW MIR lasers

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Ahmed Lobad and L.A. (Vern) Schlie

Air Force Research Laboratory, DELS 3550 Aberdeen Ave SE Albuquerque, NM 87112  
phone: (505)853-3449, fax: (505)846-5041, [ahmed.lobad@kirtland.af.mil](mailto:ahmed.lobad@kirtland.af.mil)

**Abstract:** We investigate the intervalence band absorption in InAs/InGaSb/InAs type-II MIR lasers using a nonlinear pump-probe spectroscopy technique. We are able to monitor the increase of the IVA absorption cross section, its influence on Auger process and carrier heating.

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## 1. Introduction

Type-II QW antimonide based MIR lasers have advanced rapidly since their first demonstration in 1994, with outputs reaching 10 W at low temperatures. However their performance at high temperatures fall short of theoretical expectations. Intervalence band absorption (IVA) that is resonant with the interband lasing energy has been suggested to be culprit for the high internal losses at higher temperatures. The IVA absorption cross section has so far been estimated from band structure calculation since it is not possible to measure the induced IVA process.

We used a Ti:Saph-pumped PPLN-OPO producing tunable idler pulses at  $\sim 4 \mu\text{m}$  and signal pulses  $\sim 1 \mu\text{m}$ . The signal was used to excite the carriers with the probe measuring the gain dynamics. The laser samples incorporated 6 type-II quantum placed  $1000\text{\AA}$ . Each type-II well is comprised of  $24 \text{\AA}$  thick InGaSb hole well sandwiched by two  $21 \text{\AA}$  InAs electron wells [1].

To resolve the intervalence absorption process ( $\alpha_{IVA}$ ) from the dominant interband bleaching ( $\alpha_{cv}$ ) we used a nonlinear pump-probe technique that uses two pump beams chopped at different frequencies and the spectrally resolved probe transmission/absorption nonlinearity is measured at their sum frequencies. We showed that the magnitude and signature of the nonlinear signal can determine position of the quasi Fermi energy and the carrier temperature [2]. The linear and sum frequency transmission spectra are given by,

$$\Delta T(n, \epsilon) \propto \alpha_{cv} [f_c(n, \epsilon) + f_h(n, \epsilon)] - \alpha_{IVA}(\epsilon) f_h(n, \epsilon) \quad (1)$$

$$\Delta T_{SF}(n, \epsilon) \propto \Delta T(2n, \epsilon) - 2\Delta T(n, \epsilon) \quad (2)$$

In Fig.1 the sum frequency spectrum normalized to the linear transmission transient ( $\Delta T_{SF}(n, \epsilon)/\Delta T(n, \epsilon)$ ) is plotted for different temperatures at a probe delay of 200 ps from the two pump pulses. This delay is long enough to insure that the carriers have cooled to the lattice temperature while short enough to ignore carrier recombination. At low density the spectra in Fig 1(a) shows the band filling contribution with a negative signal (saturating dependence) crossing over to a superlinear dependence at the quasi-Fermi energy. The IVA process shows up in Fig 1(b) as a negative bias of the whole spectra and a negative contribution at the high-energy side with increased temperature and excitation density. The spectra are inhomogeneously broadened due to interface roughness.

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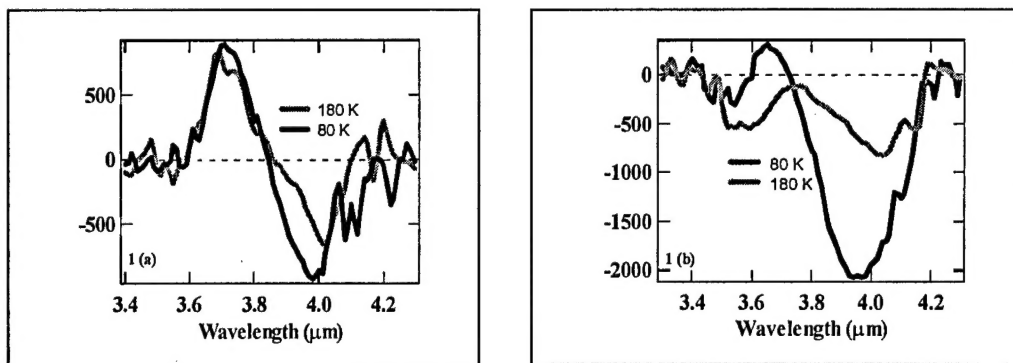


Fig. 1 Sum frequency spectrum at 200 ps probe delay for low density (a) and high density excitation (b).

We correlate the increase of the IVA signal with the decrease of carrier lifetime. This is consistent with a resonance enhancement of the *ppn* Auger process between the intervalence transition and the bandgap. We also show that in a laser operation the IVA process is not only passive internal loss mechanism but is also a carrier heating mechanism that clamps intracavity lasing power.

#### References

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